January 15, 2002

Near and Future Coal Combustion System Developments and Products

Evolution of Combustion Technology to Support National Energy Needs -
Orlando, FL

John Marion - ALSTOM Power Inc.

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January 14-16, 2002

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Outline of Talk

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- Renewed USA interest in coal
- Today's State of the Art
- Roadmap to Future Coal Combustion Options for Power

Solid Fuel vs. Gas Today..

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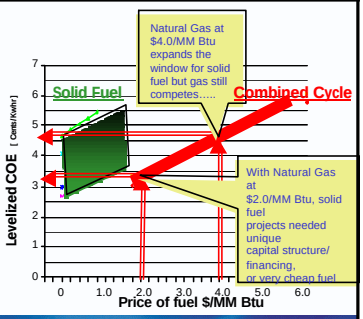
Market Needs

- Lowest Cost of Electricity
- Fuel Diversification
- Maximum Availability
- Low Emission Levels
- Commercial Solutions



240 GW's gas and 50 GW's coal power projects announced since 2000

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- Renewed USA interest in coal
- Today's State of the Art
- Roadmap to Future Coal Combustion Options for Power

Coal Combustion Power Dominates Current Generation

Steam Power Plants Segmentation

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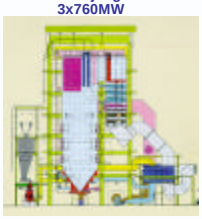
CFB boilers

Provence 4
The largest operating CFB boiler in the world

PC boilers

Manjung
3x760MW



- Also by steam conditions
  - Subcritical (both PC and CFB)
  - Supercritical (thus far commercial units are all PC)

USA Projects are 33% CFB, 67% PC and 25% Supercritical

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Subcritical Boilers

~ 1,200,000 MW of global installed capacity

Birchwood Project

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USA

- Owner: Mirant
- Unit: 1x 240 MW Subcritical Controlled Circulation
- Commissioning: 1996 (3 years from notice to proceed)
- Fuel: Eastern Bituminous
- Steam Conditions:
  - Design Pressure: 2950 psig
  - Superheat: 1005°F
  - Reheat: 1005°F

State-of-the-art Emission Control:

- Low NO_x TFS 2000™ firing system (including Dynamic™ Classifier) + SCR: 0.1 lbs/MM BTU NOx emissions
- Dry scrubber FGD: 0.07 lbs/MM BTU SO2 emissions

One of the Cleanest Coal Plants

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Supercritical Boilers

~ 250,000 MW of installed global capacity

Typical Supercritical Plants today

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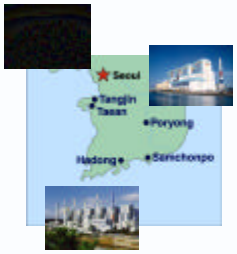
Korea



20 units x 500 MW = 10,000 MW

- 18 Units in Operation
- Advanced Sliding Pressure Supercritical Designs Provide High Efficiency Across All Load Regimes
- Units capable of continuous cycling and/or two-shift Daily Start/Stop (DSS)
- 90-minute Fast Start for DSS Duty
- Low NOx Burners consistently achieve < Korea limit of 200 ppm
- Next Generation Under Construction
  - Yunghung 2 x 800 MW

Standardized Design: Reduced Fuel Costs, Enabling Cycling, Lower Maintenance

State of the Art Supercritical

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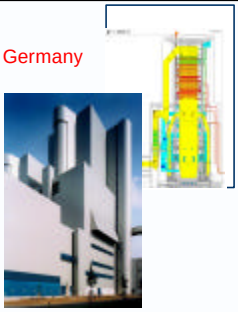
Germany



Niederaußem: 1,000 MW

- Owner RWE Energie
- Fuel Brown Coal
- Design Pressure 4206 PSIG
- SH/RH Temperature 1076/1112 F
- Commissioning 2002

Schwarze Pumpe: 2x 800 MW

- Owner VEAG
- Fuel Brown coal
- Design Pressure 3940 PSIG
- Temperature 1017/1050 F
- Commissioning 1997

Leader in HP/High Temperature Supercritical Units

Supercritical = Lower Emissions/kwh

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	Subcritical		Supercritical	
Net Plant Efficiency (HHV)				
	34%	37%	**41%**	
	Base	Base-8%	**Base-17%**	
Total Emissions Rate (g/KWhe)				
	1008	926	**835**	CO2
	2.41	2.22	**2.00**	NOx
	7.43	6.82	**6.16**	SO2
	0.19	0.17	**0.15**	Part.

Comparable Costs with Emissions & Efficiency Benefits

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Circulating Fluidized Bed Boilers

Circulating Fluidized Bed

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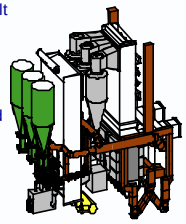
- Utilize lower cost solid fuels which are difficult to burn
- Fuel flexibility enables low cost spot market purchases
- Inherent Low NOx
  - Low combustion temperatures and staged combustion; also amenable to in-furnace (cyclone) ammonia injection for SNCR
  - NOx emissions from 0.06 to 0.25 lbs/MM BTU
- Inherent Low SOx as a result of limestone injection
  - Typical removals of 90 - 97%+; up to 98.5% with secondary equipment



Economic Utilization of Low Cost Fuels

Recent North American CFBs

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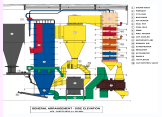
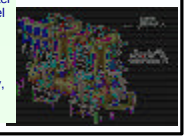
Seward: 2 x 250 MW
- Customer: Reliant Energy Seward, LLC
- Fuel: Waste Coal
- Commissioning: 2004
- Wheaton, Pa.

Guyama: 2 x 250 MW
- Customer: AES
- Fuel: Bituminous Coal
- Commissioning: 2002
- Guyama, Puerto Rico



Tamuin: 4 x 130 MW
- Customer: Sithe/ALSTOM
- Fuel: Pet Coke
- Commissioning: 2002
- Tamuin, Mexico

Redhills: 2 x 250 MW
- Customer: Bechtel Owner: Tractebel
- Fuel: Lignite
- Commissioning: 2001
- Choctaw County, Ms.



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- Renewed USA interest in coal
- Today's State of the Art
- Roadmap to Future Coal Combustion Options for Power

Roadmap for Coal Combustion Power

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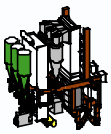
ALSTOM's view includes four (4) legs to advance coal combustion based power technology:

- Ultra-supercritical steam conditions
  - increase efficiency
- Circulating Fluid Bed (CFB) and "advanced CFBs"
  - low costs, low emissions, fuel flexibility
- Emissions controls
  - for new and existing, and integrated and post
- CO2 Capture



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Ultra-supercritical Steam Power Plant Development

Ultrasupercritical technology:
Efficiency improvements :

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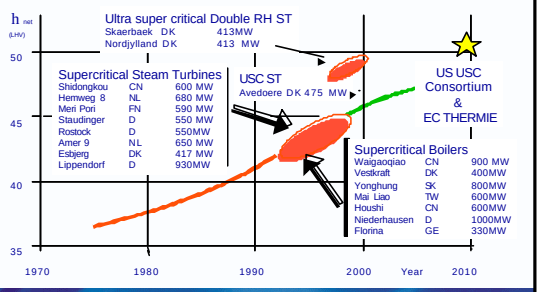

Ultra-supercritical technology Trend

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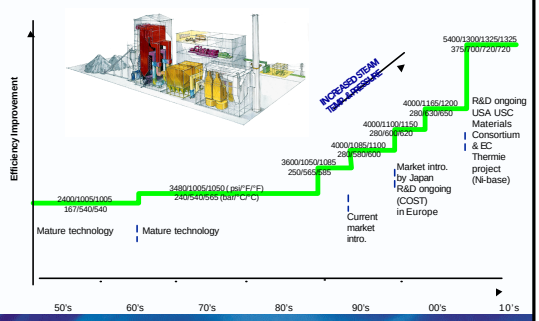

Cost Effective Materials are Key

Partnership:
Ultrasupercritical Materials

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- DOE, the State of Ohio Office of Coal Development and industry have teamed to develop next generation technology which will provide efficiency and environmental gains
- A uniquely qualified industry team - Energy Industry of Ohio, ***all*** the major US boiler manufacturers, a renowned national lab, Ohio organizations, and EPRI
- An aggressive goal - 1400ºF steam temperature
  - Looks beyond Japanese and European practice and materials to where US alloys may be best

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Future Circulating Fluidized Bed Boilers and "Advanced CFB's"

Circulating Fluidized Bed (CFB) Systems

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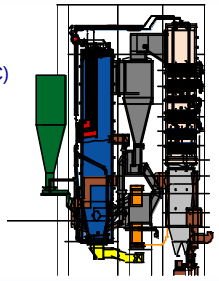
- Reduce Costs (new designs)
- Ultra Clean (integrated APC)
- Grow in Size (up to 600 MW USC)
- Enable Re - Powering
- Enable CO2 capture from combustion based power generation



"Advanced CFB" or "Circulating Moving Bed [CMB]"

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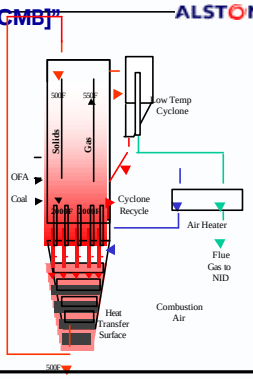
- Separate heat transfer from combustion
- More effective surface allows supercritical steam conditions at lower cost
- Lower cost than ordinary CFB for conventional duty
- Lower auxiliary power
- Potential Pathway to in situ CO2 capture



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Environmental Controls Development

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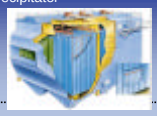
Environmental Controls

Wet & Dry Flue Gas Desulphurisation

Mercury Control

Wet and Dry Electrostatic Precipitator



De NOx

Developments in Synergy for New & Existing Plants

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Development of CO2 Capture from Combustion Systems

CO2 Capture in Combustion Systems

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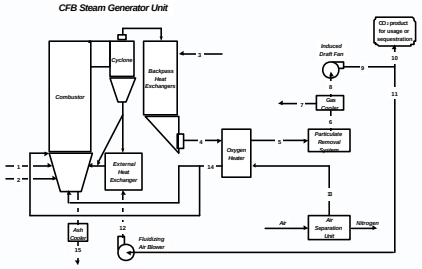
- **"Tail-end" CO_2 capture**
  - adsorption/stripping process (MEA,MEA/MDEA, and physical absorbents)
- **Oxygen combustion**
  - internal (membrane) or external (ASU) O_2
- **Other options**
  - oxidation/reduction cycles
  - carbonate capture
  - chemical looping

Innovative technology options just now emerging

Simplified System Diagram for a New Oxygen-Fired Circulating Fluidized Bed

(Concept for Minimum Fluegas re-circulation)

CFB Steam Generator Unit



Material Flow Stream Identification

Carbonate Cycle for CO_2 Capture

Below 750C….

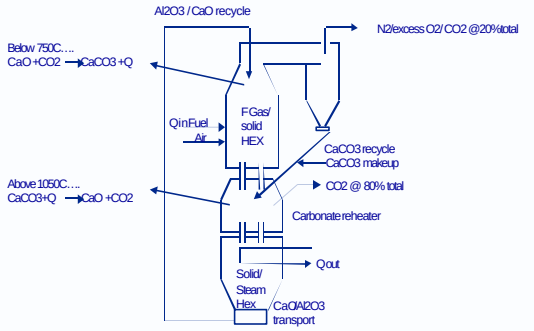
CaO +CO2 ▸ CaCO3 +Q

Above 1050C….

CaCO3+Q ▸ CaO +CO2

Potential combustion process with FBC's

CMB with CO2 Capture

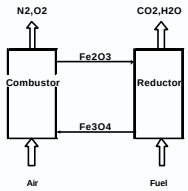


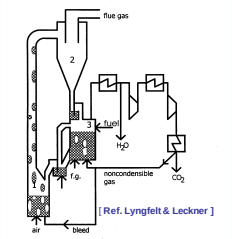
CMB with CO2 Capture

Potential Advantages:

- **Produces a slipstream with > 95% CO2**
- **Approx 80% capture of CO2**
- **Air blown -- No O2 feed**
- **No energy penalty before CO2 liquefaction**
- **Sorbent lost to the CO2 cycle is usable by FGD for SO2 capture**
- **A CFB system could capture 30 - 40% of CO2. This could be used as a more near term solution.**
  - CFB in 4 - 5 years
  - CMB in 5 - 8 years

CO2 Capture through Chemical Looping





[Ref. Lyngfelt & Leckner]

- **Atmospheric Pressure**
- **Oxygen carriers (Cu, Cd,Ni, Mn, Fe, Co)**
- **Potential combustion process with interconnected FBC's**

How Do We Get to the Future?

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- **Technology Roadmap**
- **Price** the Roadmap
- **National Energy Strategy** that values coal as an energy option for America
- **Collaboration** between Government and Industry

Roadmap for the Future

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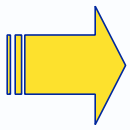
CURC - Coal Utilization Research Council

An ad hoc group of coal suppliers, users, transportation, and equipment supplier organizations with the common interest to define and realize a vision for the future of coal power through industry/government collaboration



www.coal.org

Coal Technologies

Technology	Technology Status
Supercritical Pulverized Coal w/Environmental Control	●
Circulating Fluidized Bed w/Environmental Control	●
Advanced Environmental Controls	◗
Ultrasupercritical	◗
Gasification with Current Gas Turbines	●
Advanced Gasification with Fuel Cells or Combined Cycle	◗
Carbon Sequestration	○
Co-production Transport Fuels/Chemicals/Hybrids	○

CURC advocates that Alternate Options should be Pursued

Advanced Combustion-based Steam Power Plant Roadmap

CURC December, 2001

Attributes	Today	2005	2010	2015	2020
Captial Cost	1100	1000	900	800	800
Efficiency	41	44	45	46	50
Availability	95	95	95	95	95
SO2 Removal %	98	98.5	98.5	99	99+
Nox (lbs/Mbtu)	0.1	0.1	0.05	0.05	0.01
Hg Removal %	n/a	80-90	90-95	90-96	95+
Waste Utilization	30	50	75	75	90+
Particulate Emis. (lb/Mbtu)	0.03	0.01	0.01	<.01	<.01
Steam Temperature	1100	1150	1200	1250	1400
Steam Pressure	3600	4000	4000	5000	5600
Development		alloys for ≤1400; steam turbine; innov. Boiler & plant designs; APC integration (Sox/Hg/Part)	valves for ≤1400; steam turbine; innov. Boiler & plant designs; APC integration (Sox/Hg/Part)	valves for ≤1400; steam turbine; innov. Boiler & plant designs; APC integration (Sox/Hg/Part)	shift R&D to CO2 capture
Demonstration	1100+ F PC; 300 MW CFB: APC Int. CFB	1)1150F PC (700 MW); 2) Supercritical CFB;	1) 1200 F PC (700 MW); 2) Adv. CFB (50 MW)	1) 1250 F PC (700 MW); 2) 600 MW CFB; 3)Adv. CFB (250 MW)	1) 1400 F PC (700 MW);
R&D cost	0	83	50	42	10
Demonstration Cost	0	445	270	580	220
Total Cost	0	528	320	622	230

Details of Advanced Combustion-based Steam Power Plant Research and Development

CURC December, 2001

	Today		2005		2010		2015		2020	
R&D		MUSD		MUSD		MUSD		MUSD		MUSD
		0	development and testing of alloys up to 1400 F	35	development and testing of valves for up to 1400	2	development and testing of valves for up to 1401	2	note, by this time, shift R&D to CO2 capture; see separate roadmap]	
		0	Design studies of innovative plant designs	3	Design studies of innovative plant designs	3				
			Steam Turbine development	5	Steam Turbine development	5		5		
			CFB cost reduction development	10	CFB cost reduction development	10				
		0	advanced CFB developmentn to enable high temp. cycles and future CO2 capture	20	2nd gen. advanced CFB developmentn to enable high temp. cycles and future CO2 capture	20	advanced CFB developmentn to enable high temp. cycles and future CO2 capture	25		
		0	integrated APC in CFB development	10	integrated APC in CFB development	10	integrated APC in CFB development	10	Integrated APC in CFB development	10
			APC development for PC: in existing plants roadmap		APC development for PC: in existing plants roadmap		APC development for PC: in existing plants roadmap			
			CO2 capture for combustion systems: in CO2 roadmap		CO2 capture for combustion systems: in CO2 roadmap		CO2 capture for combustion systems: in CO2 roadmap			
Subtotal:		0		83		50		42		10

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Details of Advanced Combustion-based Steam Power Plant Research and Development

CURC December, 2001

Demonstrations										
		0	1150 F PC plant demo. (700 MW)	215	1200 F PC plant demo. (700 MW)	220	1250 F PC plant demo. (700 MW)	220	1400 F PC plant demo. (700 MW)	220
			supercritical CFB demonstration	200			600 MW CFB	180		
			Integrated SO2/Hg/Part. APC in CFB	30	Small demo. (50 MW) "adv. CFD repowerring demo.	50	Large Demo. (250 MW) "adv. CFB demo.	180		
			APC for PC in existing plant roadmap		APC for PC in existing plant roadmap		APC for PC in existing plant roadmap		APC for PC in existing plant roadmap	
Subtotal:		0		445		270		580		220

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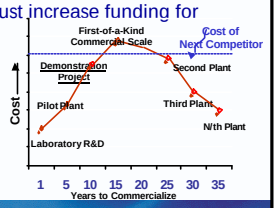
How Do We Get to the Future?

ALSTOM

- National Energy Strategy that recognizes environmental requirements and energy supply realities: Coal is America's most abundant energy resource
- Government and industry must increase funding for advanced coal research
- Clean Coal Power Initiative DOE CCPI
  - Proposed 10-year Bush clean coal effort



The overall cost of a demonstration program shared by industry and government over 20 years is approximately $10B (ref. EPRI)

Conclusions

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- Coal Competes today with Natural gas, but economics are tight.
- Major efforts need to continue on the next generation options of supercritical designs, CFBs, and "advanced CFBs".
- Environmental control development is ongoing for SOx, Hg, NOx, and byproduct use.
- Innovative technology options for CO2 capture/sequestration from combustion systems is now emerging and should be pursued.
- A government and industry collaboration is advocated to develop and demonstrate new generation options
  [DOE Combustion Systems and DOE CCPI are a great start].

coal combustion-based power is an important option

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